Hydroelectric Power

Bureau of Reclamation

Power Resources Office

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INTRODUCTION

Hydroelectric Power -- what is it?
It=s a form of energy . . . a renewable resource. Hydropower provides about 96 percent of the renewable energy in the United States. Other renewable resources include geothermal, wave power, tidal power, wind power, and solar power. Hydroelectric powerplants do not use up resources to create electricity nor do they pollute the air, land, or water, as other powerplants may. Hydroelectric power has played an important part in the development of this Nation's electric power industry. Both small and large hydroelectric power developments were instrumental in the early expansion of the electric power industry.

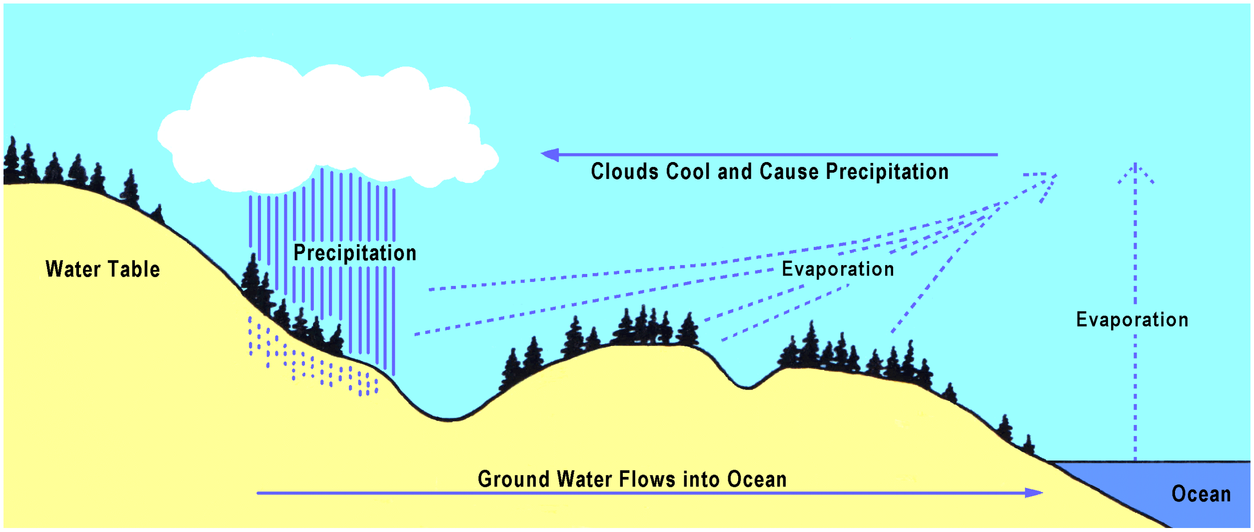
Hydroelectric power comes from flowing water . . . winter and spring runoff from mountain streams and clear lakes. Water, when it is falling by the force of gravity, can be used to turn turbines and generators that produce electricity.

Hydroelectric power is important to our Nation. Growing populations and modern technologies require vast amounts of electricity for creating, building, and expanding. In the 1920's, hydroelectric plants supplied as much as 40 percent of the electric energy produced. Although the amount of energy produced by this means has steadily increased, the amount produced by other types of powerplants has increased at a faster rate and hydroelectric power presently supplies about 11 percent of the electrical generating capacity of the United States. Hydropower is an essential contributor in the national power grid because of its ability to respond quickly to rapidly varying loads or system disturbances, which base load plants with steam systems powered by combustion or nuclear processes cannot accommodate.

Reclamation=s 58 powerplants throughout the Western United States produce an average of 42 billion kWh (kilowatt-hours) per year, enough to meet the residential needs of more than 14 million people. This is the electrical energy equivalent of about 72 million barrels of oil. Hydroelectric powerplants are the most efficient means of producing electric energy. The efficiency of today's hydroelectric plant is about 90 percent. Hydroelectric plants do not create air pollution, the fuel--falling water--is not consumed, projects have long lives relative to other forms of energy generation, and hydroelectric generators respond quickly to changing system conditions. These favorable characteristics continue to make hydroelectric projects attractive sources of electric power.

HOW HYDROPOWER WORKS

Hydroelectric power comes from water at work, water in motion. It can be seen as a form of solar energy, as the sun powers the hydrologic cycle which gives the earth its water. In the hydrologic cycle, atmospheric water reaches the earth=s surface as precipitation. Some of this water evaporates, but much of it either percolates into the soil or becomes surface runoff. Water from rain and melting snow eventually reaches ponds, lakes, reservoirs, or oceans where evaporation is constantly occurring.



Moisture percolating into the soil may become ground water (subsurface water), some of which also enters water bodies through springs or underground streams. Ground water may move upward through soil during dry periods and may return to the atmosphere by evaporation.

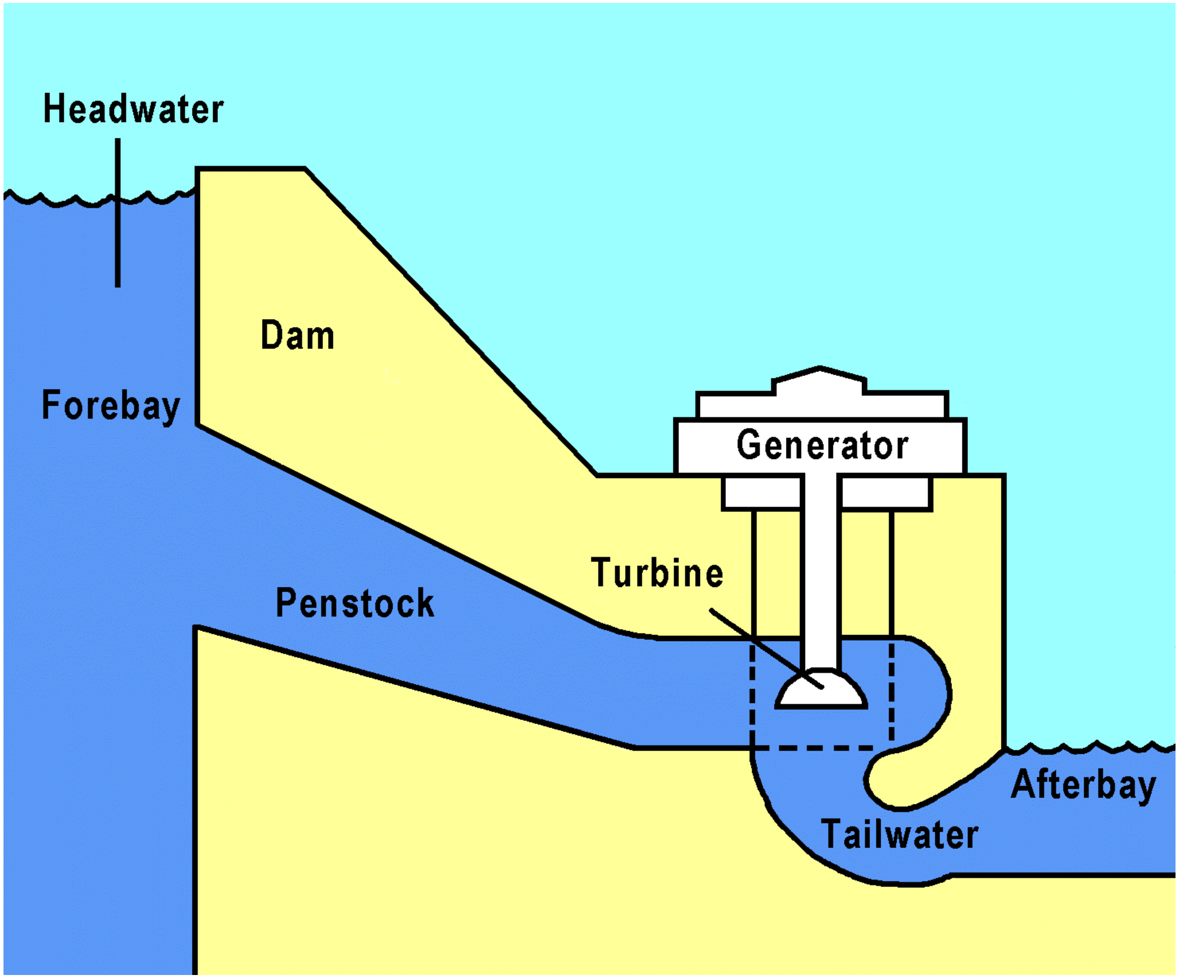
Water vapor passes into the atmosphere by evaporation then circulates, condenses into clouds, and some returns to earth as precipitation. Thus, the water cycle is complete. Nature ensures that water is a renewable resource.

Generating Power

In nature, energy cannot be created or destroyed, but its form can change. In generating electricity, no new energy is created. Actually one form of energy is converted to another form.

To generate electricity, water must be in motion. This is kinetic (moving) energy. When flowing water turns blades in a turbine, the form is changed to mechanical (machine) energy. The turbine turns the generator rotor which then converts this mechanical energy into another energy form -- electricity. Since water is the initial source of energy, we call this hydroelectric power or hydropower for short.

At facilities called hydroelectric powerplants, hydropower is generated. Some powerplants are located on rivers, streams, and canals, but for a reliable water supply, dams are needed. Dams store water for later release for such purposes as irrigation, domestic and industrial use, and power generation. The reservoir acts much like a battery, storing water to be released as needed to generate power.



The dam creates a Ahead@ or height from which water flows. A pipe (penstock) carries the water from the reservoir to the turbine. The fast-moving water pushes the turbine blades, something like a pinwheel in the wind. The waters force on the turbine blades turns the rotor, the moving part of the electric generator. When coils of wire on the rotor sweep past the generator=s stationary coil (stator), electricity is produced.

This concept was discovered by Michael Faraday in 1831 when he found that electricity could be generated by rotating magnets within copper coils.

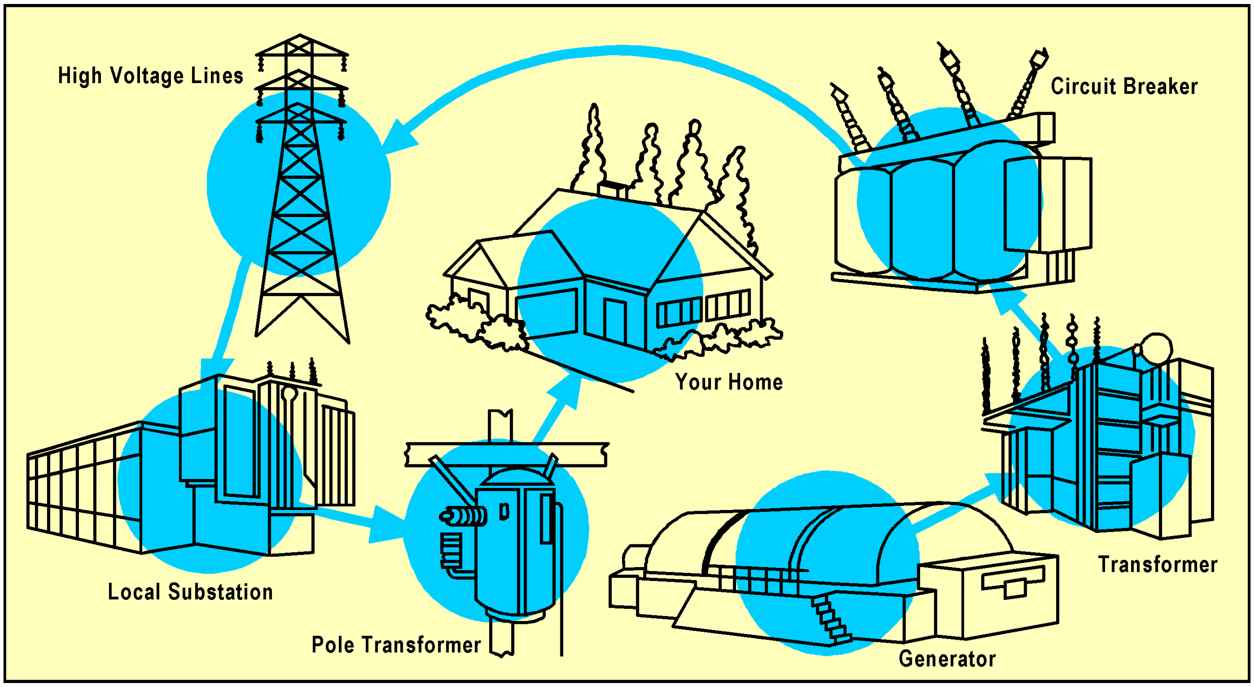
When the water has completed its task, it flows on unchanged to serve other needs.

Transmitting Power

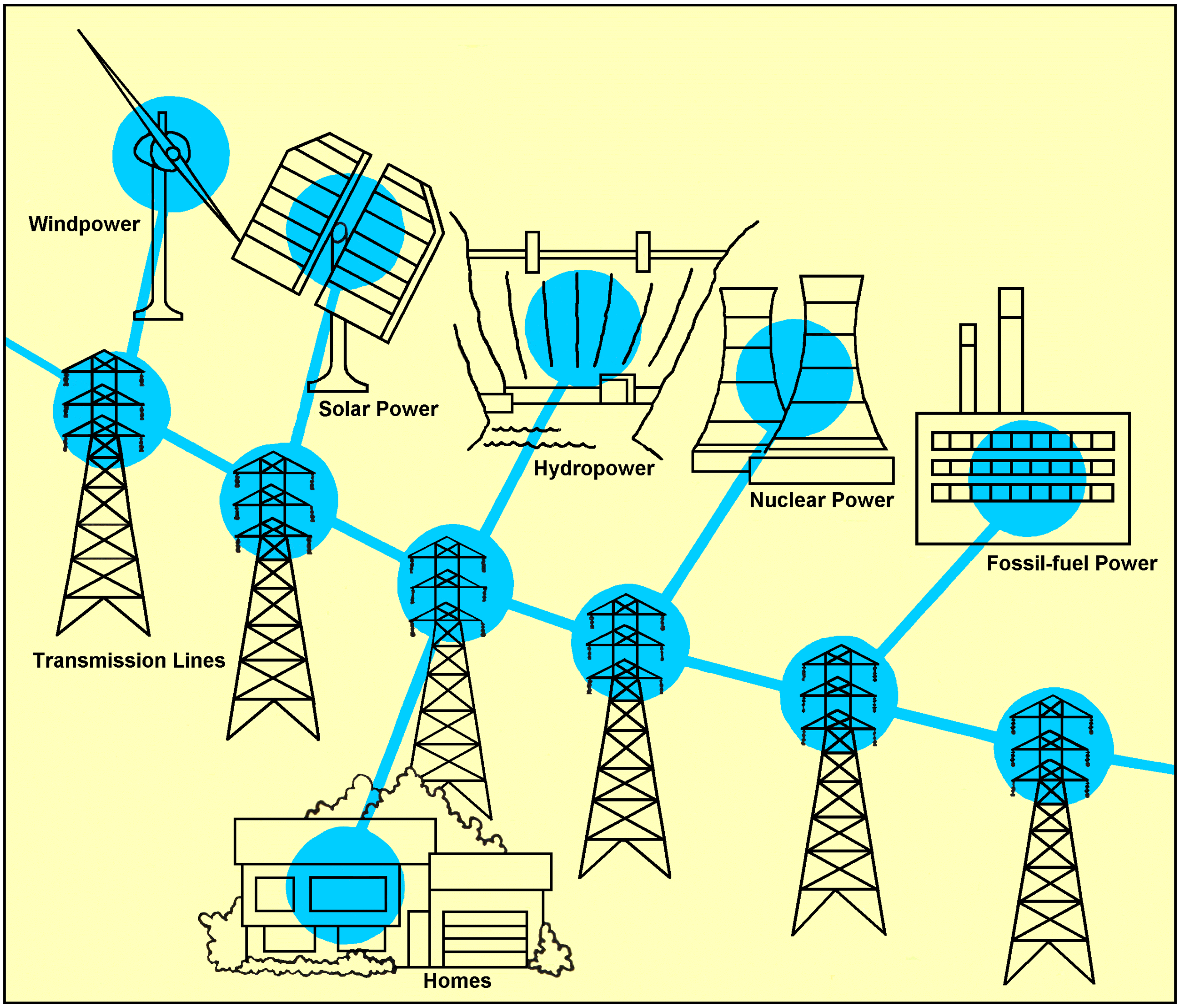
Once the electricity is produced, it must be delivered to where it is needed -- our homes, schools, offices, factories, etc. Dams are often in remote locations and power must be transmitted over some distance to its users.

Vast networks of transmission lines and facilities are used to bring electricity to us in a form we can use. All the electricity made at a powerplant comes first through transformers which raise the voltage so it can travel long distances through powerlines. (Voltage is the pressure that forces an electric current through a wire.) At local substations, transformers reduce the voltage so electricity can be divided up and directed throughout an area.

Transformers on poles (or buried underground, in some neighborhoods) further reduce the electric power to the right voltage for appliances and use in the home. When electricity gets to our homes, we buy it by the kilowatt-hour, and a meter measures how much we use.

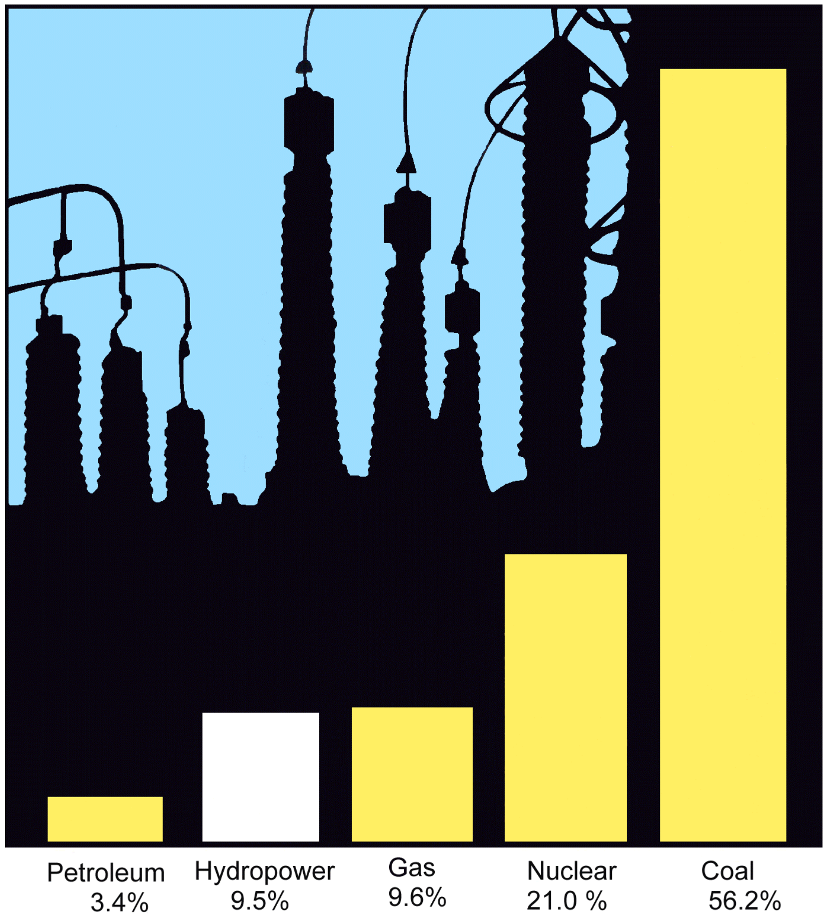


While hydroelectric powerplants are one source of electricity, other sources include powerplants that burn fossil fuels or split atoms to create steam which in turn is used to generate power. Gas-turbine, solar, geothermal, and wind-powered systems are other sources. All these powerplants may use the same system of transmission lines and stations in an area to bring power to you. By use of this Apower grid,@ electricity can be interchanged among several utility systems to meet varying demands. So the electricity lighting your reading lamp now may be from a hydroelectric powerplant, a wind generator, a nuclear facility, or a coal, gas, or oil-fired powerplant . . . or a combination of these.



The area where you live and its energy resources are prime factors in determining what kind of power you use. For example, in Washington State hydroelectric powerplants provided approximately 80 percent of the electrical power during 1996. In contrast, in Ohio during the same year, 90 percent of the electrical power came from coal-fired powerplants due to the area=s ample supply of coal.

Electrical utilities range from large systems serving broad regional areas to small power companies serving individual communities. Most electric utilities are investor-owned (private) power companies. Others are owned by towns, cities, and rural electric associations. Surplus power produced at facilities owned by the Federal Government is marketed to preference power customers (A customer given preference by law in the purchase of federally generated electrical energy which is generally an entity which is nonprofit and publicly financed.) by the Department of Energy through its power marketing administrations.



Amount of Electricity Provided by Power Sources (1998)

How Power is Computed

Before a hydroelectric power site is developed, engineers compute how much power can be produced when the facility is complete. The actual output of energy at a dam is determined by the volume of water released (discharge) and the vertical distance the water falls (head). So, a given amount of water falling a given distance will produce a certain amount of energy. The head and the discharge at the power site and the desired rotational speed of the generator determine the type of turbine to be used.

The head produces a pressure (water pressure), and the greater the head, the greater the pressure to drive turbines. This pressure is measured in pounds of force (pounds per square inch). More head or faster flowing water means more power.

To find the theoretical horsepower (the measure of mechanical energy) from a specific site, this formula is used:

$$THP = \frac{QxH}{8.8}$$

where: THP = theoretical horsepower
Q = flow rate in cubic feet per second (cfs)
H = head in feet
8.8 = a constant

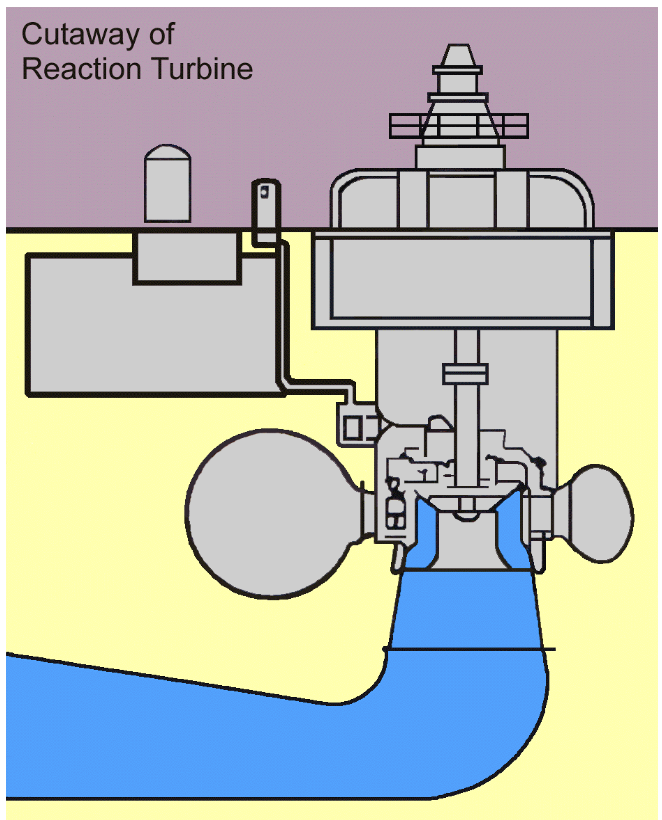
A more complicated formula is used to refine the calculations of this available power. The formula takes into account losses in the amount of head due to friction in the penstock and other variations due to the efficiency levels of mechanical devices used to harness the power.

To find how much electrical power we can expect, we must convert the mechanical measure (horsepower) into electrical terms (watts). One horsepower is equal to 746 watts (U.S. measure).

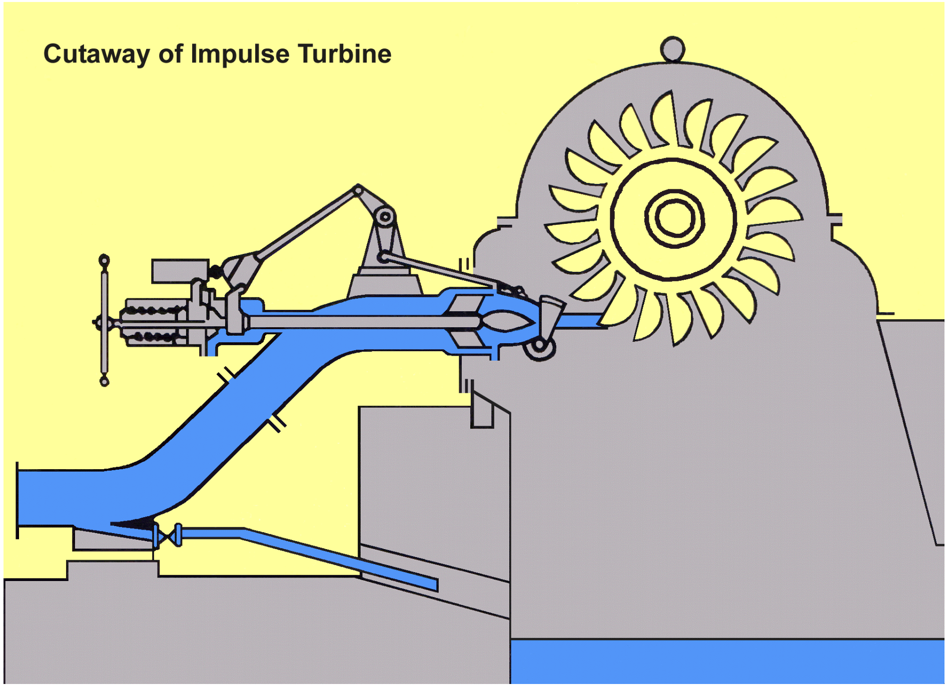
Turbines

While there are only two basic types of turbines (impulse and reaction), there are many variations. The specific type of turbine to be used in a powerplant is not selected until all operational studies and cost estimates are complete. The turbine selected depends largely on the site conditions.

A reaction turbine is a horizontal or vertical wheel that operates with the wheel completely submerged, a feature which reduces turbulence. In theory, the reaction turbine works like a rotating lawn sprinkler where water at a central point is under pressure and escapes from the ends of the blades, causing rotation. Reaction turbines are the type most widely used.



An impulse turbine is a horizontal or vertical wheel that uses the kinetic energy of water striking its buckets or blades to cause rotation. The wheel is covered by a housing and the buckets or blades are shaped so they turn the flow of water about 170 degrees inside the housing. After turning the blades or buckets, the water falls to the bottom of the wheel housing and flows out.



Modern Concepts and Future Role

Hydropower does not discharge pollutants into the environment; however, it is not free from adverse environmental effects. Considerable efforts have been made to reduce environmental problems associated with hydropower operations, such as providing safe fish passage and improved water quality in the past decade at both Federal facilities and non-Federal facilities licensed by the Federal Energy Regulatory Commission.

Efforts to ensure the safety of dams and the use of newly available computer technologies to optimize operations have provided additional opportunities to improve the environment. Yet, many unanswered questions remain about how best to maintain the economic viability of hydropower in the face of increased demands to protect fish and other environmental resources.

Reclamation actively pursues research and development (R&D) programs to improve the operating efficiency and the environmental performance of hydropower facilities.

Hydropower research and development today is primarily being conducted in the following areas:

Fish Passage, Behavior, and Response
Turbine-Related Projects
Monitoring Tool Development
Hydrology
Water Quality
Dam Safety
Operations & Maintenance
Water Resources Management.

Reclamation continues to work to improve the reliability and efficiency of generating hydropower. Today, engineers want to make the most of new and existing facilities to increase production and efficiency. Existing hydropower concepts and approaches include:

-- Uprating existing powerplants
-- Developing small plants (low-head hydropower)
-- Peaking with hydropower
-- Pumped storage
-- Tying hydropower to other forms of energy

Uprating

The uprating of existing hydroelectric generator and turbine units at powerplants is one of the most immediate, cost-effective, and environmentally acceptable means of developing additional electric power. Since 1978, Reclamation has pursued an aggressive uprating program which has added more than 1,600,000 kW to Reclamation's capacity at an average cost of $69 per kilowatt. This compares to an average cost for providing new peaking capacity through oil-fired generators of more than $400 per kilowatt. Reclamation's uprating program has essentially provided the equivalent of another major hydroelectric facility of the approximate magnitude of Hoover Dam and Powerplant at a fraction of the cost and impact on the environment when compared to any other means of providing new generation capacity.

Low-head Hydropower

A low-head dam is one with a water drop of less than 65 feet and a generating capacity less than 15,000 kW. Large, high-head dams can produce more power at lower costs than low-head dams, but construction of large dams may be limited by lack of suitable sites, by environmental considerations, or by economic conditions. In contrast, there are many existing small dams and drops in elevation along canals where small generating plants could be installed. New low-head dams could be built to increase output as well. The key to the usefulness of such units is their ability to generate power near where it is needed, reducing the power inevitably lost during transmission.

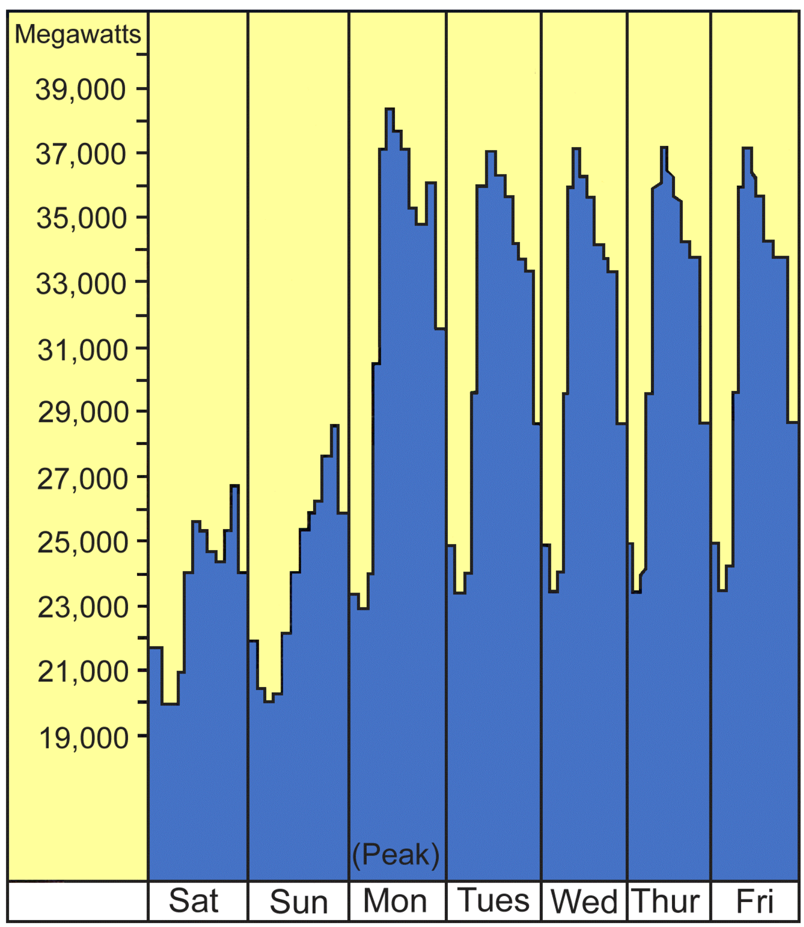
Peaking with Hydropower

Demands for power vary greatly during the day and night. These demands vary considerably from season to season, as well. For example, the highest peaks are usually found during summer daylight hours when air conditioners are running.

Nuclear and fossil fuel plants are not efficient for producing power for the short periods of increased demand during peak periods. Their operational requirements and their long startup times make them more efficient for meeting baseload needs.

Since hydroelectric generators can be started or stopped almost instantly, hydropower is more responsive than most other energy sources for meeting peak demands. Water can be stored overnight in a reservoir until needed during the day, and then released through turbines to generate power to help supply the peakload demand. This mixing of power sources offers a utility company the flexibility to operate steam plants most efficiently as base plants while meeting peak needs with the help of hydropower. This technique can help ensure reliable supplies and may help eliminate brownouts and blackouts caused by partial or total power failures.

Today, many of Reclamation=s 58 powerplants are used to meet peak electrical energy demands, rather than operating around the clock to meet the total daily demand. Increasing use of other energy-producing powerplants in the future will not make hydroelectric powerplants obsolete or unnecessary. On the contrary, hydropower can be even more important. While nuclear or fossil-fuel powerplants can provide baseloads, hydroelectric powerplants can deal more economically with varying peakload demands. This is a job they are well suited for.



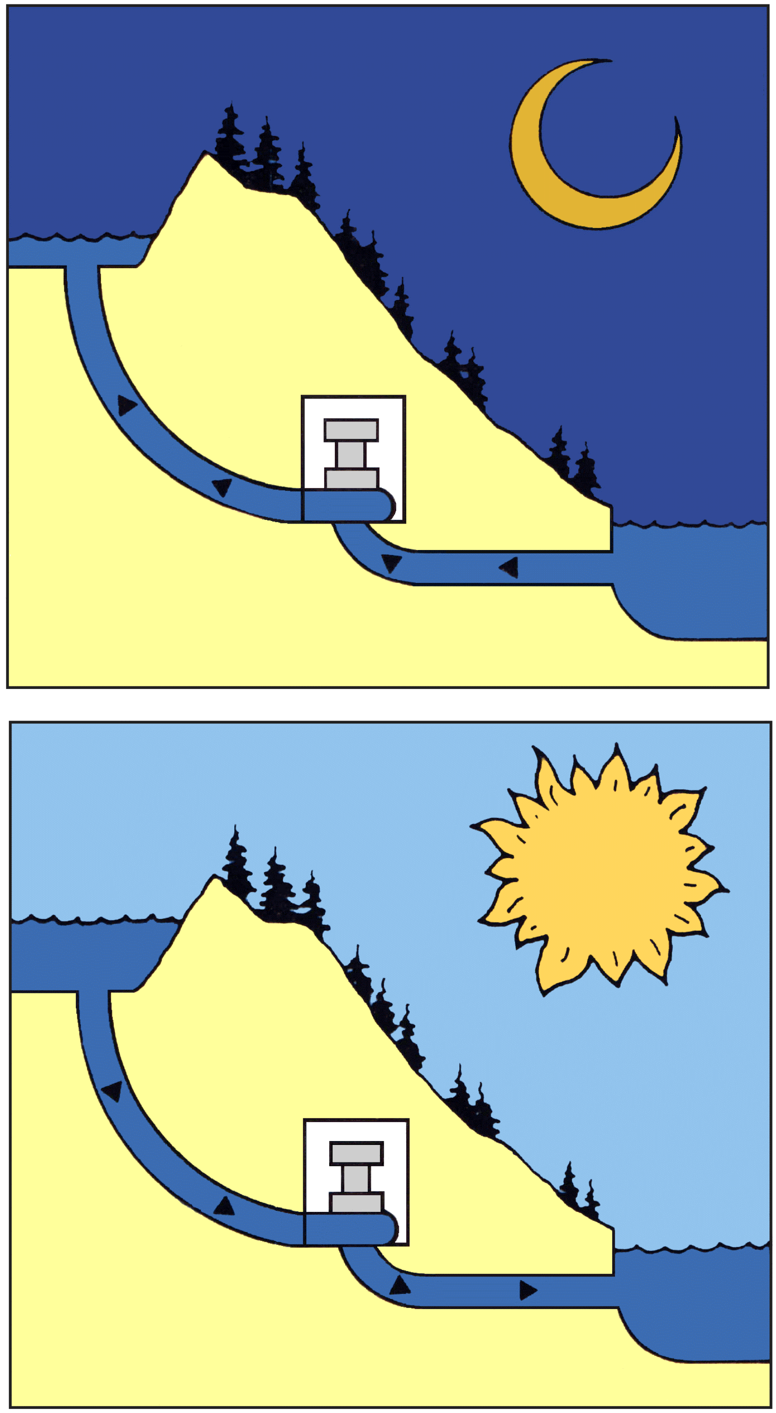
Typical Weekly Load Curve of a Large Electric Utiliity

Pumped Storage

Like peaking, pumped storage is a method of keeping water in reserve for peak period power demands. Pumped storage is water pumped to a storage pool above the powerplant at a time when customer demand for energy is low, such as during the middle of the night. The water is then allowed to flow back through the turbine-generators at times when demand is high and a heavy load is place on the system.

The reservoir acts much like a battery, storing power in the form of water when demands are low and producing maximum power during daily and seasonal peak periods. An advantage of pumped storage is that hydroelectric generating units are able to start up quickly and make rapid adjustments in output. They operate efficiently when used for one hour or several hours.

Because pumped storage reservoirs are relatively small, construction costs are generally low compared with conventional hydropower facilities.



Top
At night when customer demand for energy is low. water is pumped to a storage pool above the dam.

Bottom
When demand is high and a heavy load is placed on the system, water is allowed to flow back through the turbine-generators.

Tying Hydropower to Other Energy Forms

When we hear the term Asolar energy,@ we usually think of heat from the sun=s rays which can be put to work. But there are other forms of solar energy. Just as hydropower is a form of solar energy, so too is windpower. In effect, the sun causes the wind to blow by heating air masses that rise, cool, and sink to earth again. Solar energy in some form is always at work -- in rays of sunlight, in air currents, and in the water cycle.

Solar energy, in its various forms, has the potential of adding significant amounts of power for our use. The solar energy that reaches our planet in a single week is greater than that contained in all of the earth=s remaining coal, oil, and gas resources. However, the best sites for collecting solar energy in various forms are often far removed from people, their homes, and work places. Building thousands of miles of new transmission lines would make development of the power too costly.

Because of the seasonal, daily, and even hourly changes in the weather, energy flow from the wind and sun is neither constant nor reliable. Peak production times do not always coincide with high power demand times. To depend on the variable wind and sun as main power sources would not be acceptable to most American lifestyles. Imagine having to wait for the wind to blow to cook a meal or for the sun to come out from behind a cloud to watch television!

As intermittent energy sources, solar power and wind power must be tied to major hydroelectric power systems to be both economical and feasible. Hydropower can serve as an instant backup and to meet peak demands.

Linking windpower and hydropower can add to the Nation=s supply of electrical energy. Large wind machines can be tied to existing hydroelectric powerplants. Wind power can be used, when the wind is blowing, to reduce demands on hydropower. That would allow dams to save their water for later release to generate power in peak periods.

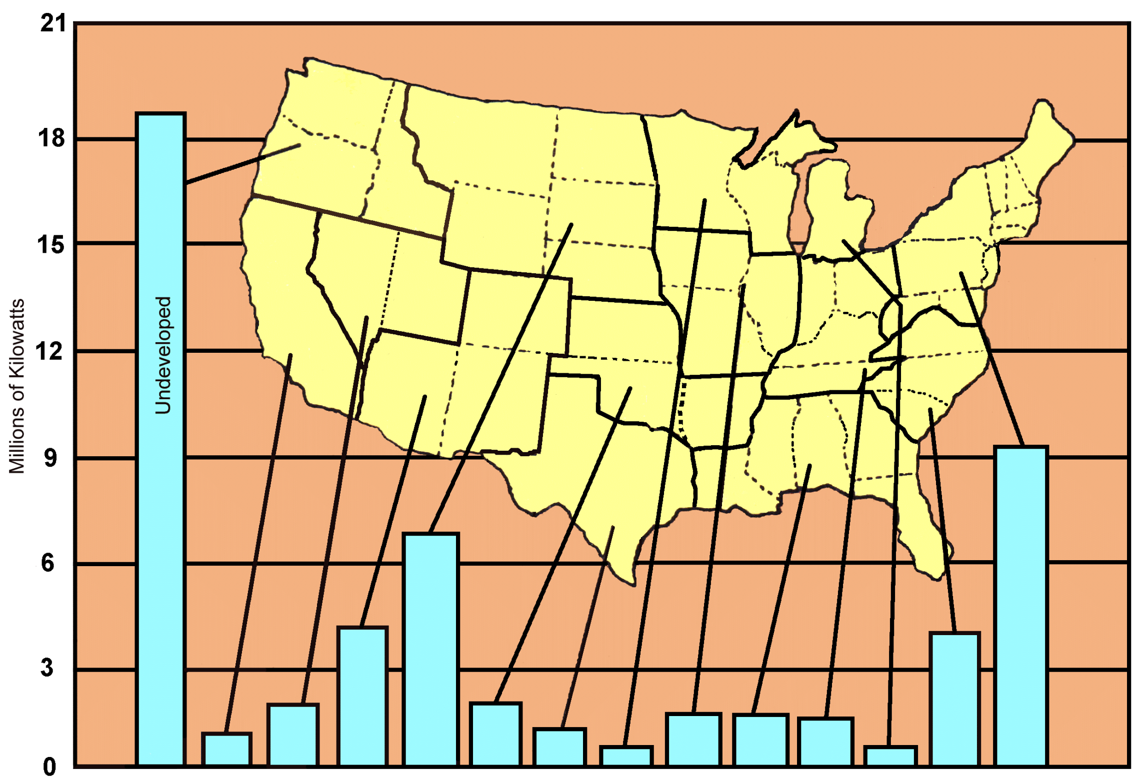
The benefits of solar power and wind power are many. The most valuable feature of all is the replenishing supply of these types of energy. As long as the sun shines and the wind blows, these resources are truly renewable.

Future Potential

What is the full potential of hydropower to help meet the Nation=s energy needs? The hydropower resource assessment by the Department of Energy=s Hydropower Program has identified 5,677 sites in the United States with acceptable undeveloped hydropower potential. These sites have a modeled undeveloped capacity of about 30,000 MW. This represents about 40 percent of the existing conventional hydropower capacity.

A variety of restraints exist on this development, some natural and some imposed by our society. The natural restraints include such things as occasional unfavorable terrain for dams. Other restraints include disagreements about who should develop a resource or the resulting changes in environmental conditions. Often, other developments already exist where a hydroelectric power facility would require a dam and reservoir to be built.

Finding solutions to the problems imposed by natural restraints demands extensive engineering efforts. Sometimes a solution is impossible, or so expensive that the entire project becomes impractical. Solution to the societal issues is frequently much more difficult and the costs are far greater than those imposed by nature. Developing the full potential of hydropower will require consideration and coordination of many varied needs.



Undeveloped Hydroelectric Power

Potential for development depends on many interrelated factors.

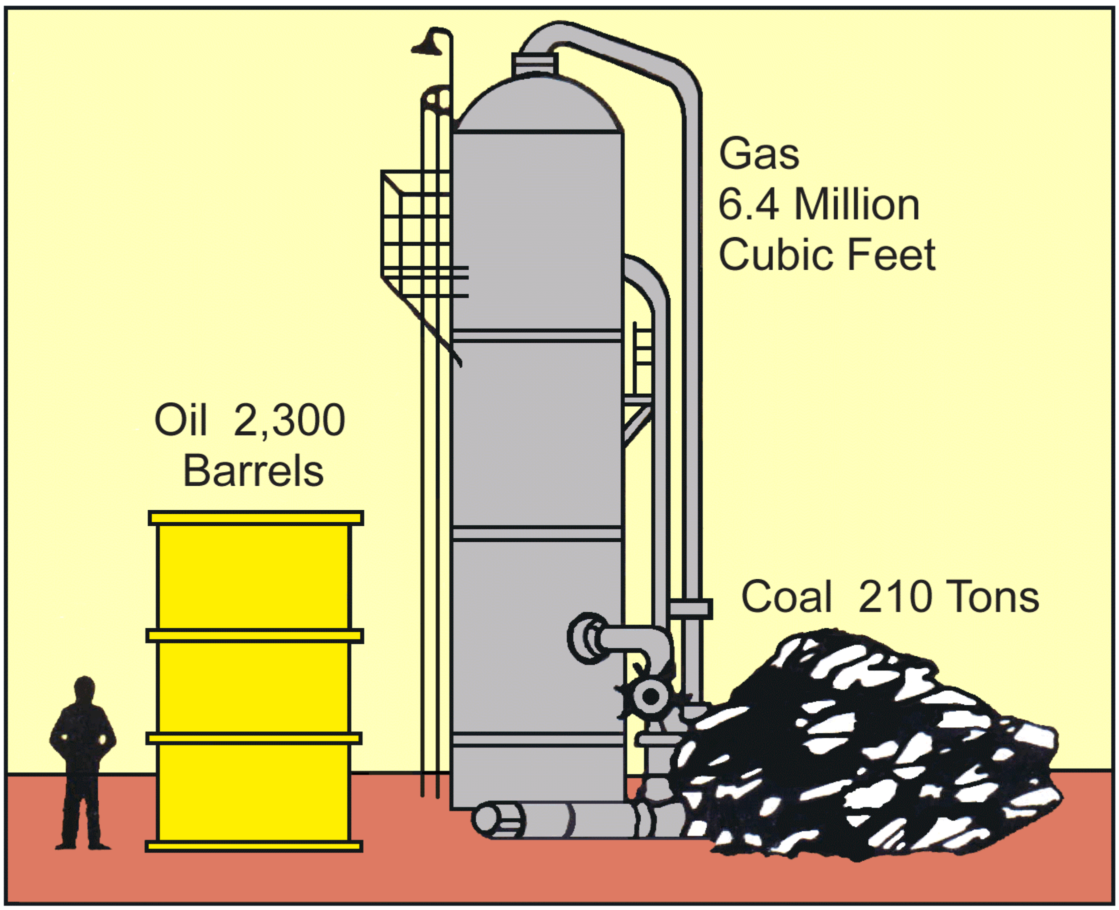
Hydropower, the Environment, and Society

It is important to remember that people, and all their actions, are part of the natural world. The materials used for building, energy, clothing, food, and all the familiar parts of our day-to-day world come from natural resources.

Our surroundings are composed largely of the Abuilt environment@ -- structures and facilities built by humans for comfort, security, and well-being. As our built environment grows, we grow more reliant on its offerings.

To meet our needs and support our built environment, we need electricity which can be generated by using the resources of natural fuels. Most resources are not renewable; there is a limited supply. In obtaining resources, it is often necessary to drill oil wells, tap natural gas supplies, or mine coal and uranium. To put water to work on a large scale, storage dams are needed.

We know that any innovation introduced by people has an impact on the natural environment. That impact may be desirable to some, and at the same time, unacceptable to others. Using any source of energy has some environmental cost. It is the degree of impact on the environment that is crucial.



How Much Energy Each of Us Uses in a Lifetime

Some human activities have more profound and lasting impacts than others. Techniques to mine resources from below the earth may leave long-lasting scars on the landscape. Oil wells may detract from the beauty of open, grassy fields. Reservoirs behind dams may cover picturesque valleys. Once available, use of energy sources can further impact the air, land, and water in varying degrees.

People want clean air and water and a pleasing environment. We also want energy to heat and light our homes and run our machines. What is the solution?

The situation seems straightforward: The demand for electrical power must be curbed or more power must be produced in environmentally acceptable ways. The solution, however, is not so simple.

Conservation can save electricity, but at the same time our population is growing steadily. Growth is inevitable, and with it the increased demand for electric power.

Since natural resources will continue to be used, the wisest solution is a careful, planned approach to their future use. All alternatives must be examined, and the most efficient, acceptable methods must be pursued.

Hydroelectric facilities have many characteristics that favor developing new projects and upgrading existing powerplants:

-- Hydroelectric powerplants do not use up limited nonrenewable resources to make electricity.
-- They do not cause pollution of air, land, or water.
-- They have low failure rates, low operating costs, and are reliable.
--They can provide startup power in the event of a system wide power failure.

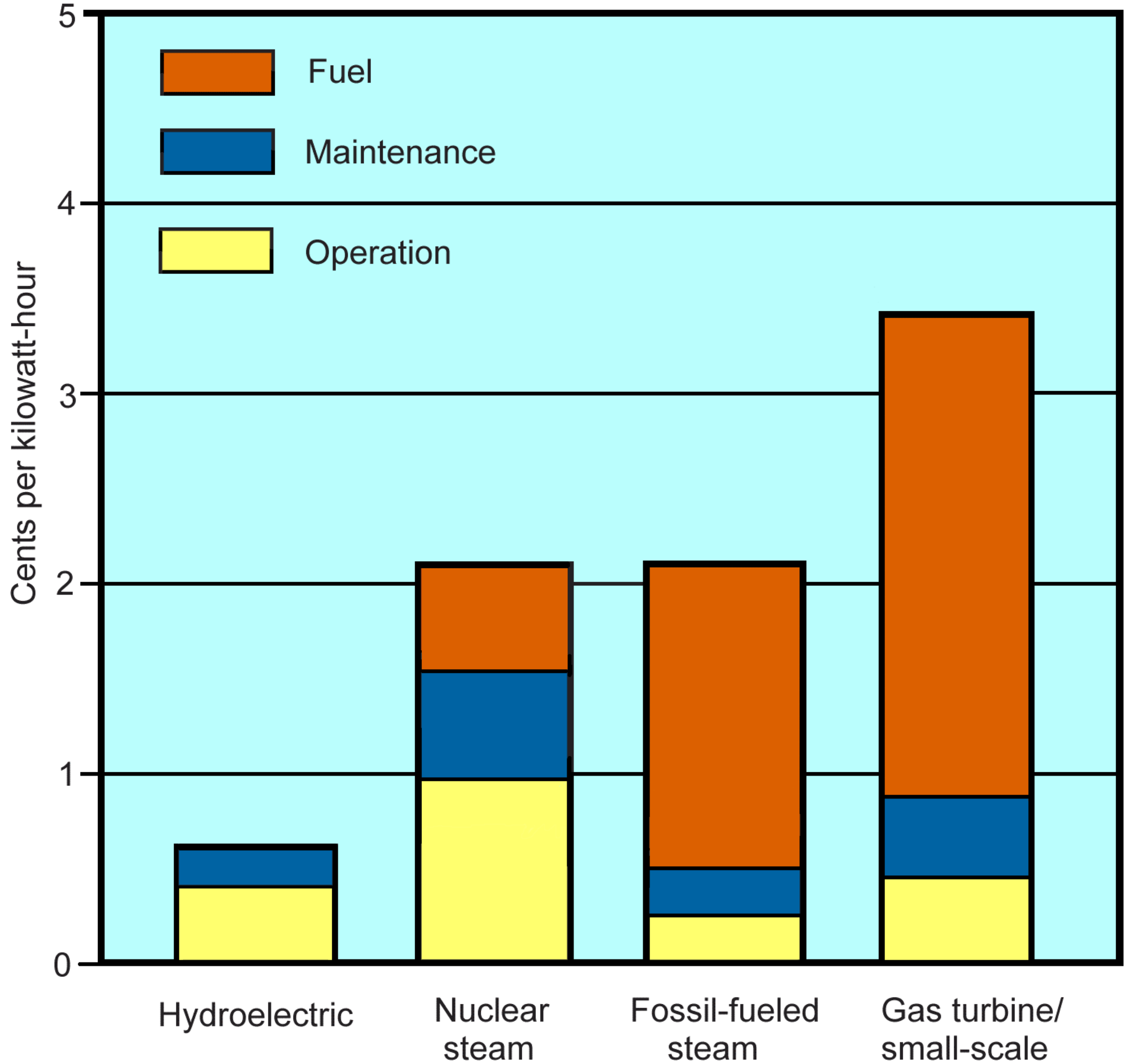
As an added benefit, reservoirs have scenic and recreation value for campers, fishermen, and water sports enthusiasts. The water is a home for fish and wildlife as well. Dams add to domestic water supplies, control water quality, provide irrigation for agriculture, and avert flooding. Dams can actually improve downstream conditions by allowing mud and other debris to settle out.

Existing powerplants can be uprated or new powerplants added at current dam sites without a significant effect on the environment. New facilities can be constructed with consideration of the environment. For instance, dams can be built at remote locations, powerplants can be placed underground, and selective withdrawal systems can be used to control the water temperature released from the dam. Facilities can incorporate features that aid fish and wildlife, such as salmon runs or resting places for migratory birds.

In reconciling our natural and our built environments there will be tradeoffs and compromises. As we learn to live in harmony as part of the environment, we must seek the best alternatives among all ecologic, economic, technological, and social perspectives.

The value of water must be considered by all energy planners. Some water is now dammed and can be put to work to make hydroelectric power. Other water is presently going to waste. The fuel burned to replace this wasted energy is gone forever and, so, is a loss to our Nation.

The longer we delay the balanced development of our potential for hydropower, the more we unnecessarily use up other vital resources.



Average Power Production Expenses per kWh, 1995 -1999

(Investor-owner electric utilities)

Hydropower is an economical source of electrical energy. It is one type of electricity that is immune to rising fuel costs. Hydropower costs above include pumped-storage.

Source: Energy Information Administration Financial Statistics of Major U.S. Investor-Owned Utilities.

HYDROPOWER -- FROM PAST TO PRESENT

By using water for power generation, people have worked with nature to achieve a better lifestyle. The mechanical power of falling water is an age-old tool. As early as the 1700's, Americans recognized the advantages of mechanical hydropower and used it extensively for milling and pumping. By the early 1900's, hydroelectric power accounted for more than 40 percent of the Nation=s supply of electricity. In the West and Pacific Northwest, hydropower provided about 75 percent of all the electricity consumed in the 1940's. With the increase in development of other forms of electric power generation, hydropower=s percentage has slowly declined to about 10 percent. However, many activities today still depend on hydropower.

Niagra Falls was the first of the American hydroelectric power sites developed for major generation and is still a source of electric power today. Power from such early plants was used initially for lighting, and when the electric motor came into being the demand for new electrical energy started its upward spiral.

The Federal Government became involved in hydropower production because of its commitment to water resource management in the arid West. The waterfalls of the Reclamation dams make them significant producers of electricity. Hydroelectric power generation has long been an integral part of Reclamation=s operations while it is actually a byproduct of water development. In the early days, newly created projects lacked many of the modern conveniences, one of these being electrical power. This made it desirable to take advantage of the potential power source in water.

Powerplants were installed at the dam sites to carry on construction camp activities. Hydropower was put to work lifting, moving and processing materials to build the dams and dig canals. Powerplants ran sawmills, concrete plants, cableways, giant shovels, and draglines. Night operations were possible because of the lights fed by hydroelectric power. When construction was complete, hydropower drove pumps that provided drainage or conveyed water to lands at higher elevations than could be served by gravity-flow canals.

Surplus power was sold to existing power distribution systems in the area. Local industries, towns, and farm consumers benefitted from the low-cost electricity. Much of the construction and operating costs of dams and related facilities were paid for by this sale of surplus power, rather than by the water users alone. This proved to be a great savings to irrigators struggling to survive in the West.

Reclamation=s first hydroelectric powerplant was built to aid construction of the Theodore Roosevelt Dam on the Salt River about 75 miles northeast of Phoenix, Arizona. Small hydroelectric generators, installed prior to construction, provided energy for construction and for equipment to lift stone blocks into place. Surplus power was sold to the community, and citizens were quick to support expansion of the dam=s hydroelectric capacity. A 4,500-kW powerplant was constructed and, in 1909, five generators were in operation, providing power to pump irrigation water and furnishing electricity to the Phoenix area.

Power development, a byproduct of water development, had a tremendous impact on the area=s economy and living conditions. Power was sold to farms, cities, and industries. Wells pumped by electricity meant more irrigated land for agriculture, and pumping also lowered water tables in those areas with waterlogging and alkaline soil problems. By 1916, nine pumping plants were in operation irrigating more than 10,000 acres. In addition, Reclamation supplied all of the residential and commercial power needs of Phoenix. Cheap hydropower, in abundant supply, attracted industrial development as well. A private company was able to build a large smelter and mill nearby to process low-grade copper ore, using hydroelectric power.

The Theodore Roosevelt Powerplant was one of the first large power facilities constructed by the Federal Government. Its capacity has since been increased from 4,500 kW to more than 36,000 kW.

Power, first developed for building Theodore Roosevelt Dam and for pumping irrigation water, also helped pay for construction, enhanced the lives of farmers and city dwellers, and attracted new industry to the Phoenix area.

During World War I, Reclamation projects continued to provide water and hydroelectric power to Western farms and ranches. This helped feed and clothe the Nation, and the power revenues were a welcome source of income to the Federal Government.

The depression of the 1930's, coupled with widespread floods and drought in the West, spurred building of great multipurpose Reclamation projects such as Grand Coulee Dam on the Columbia River, Hoover Dam on the lower Colorado River, and the Central Valley Project in California. This was the Abig dam@ period, and the low-cost hydropower produced by those dams had a profound effect on urban and industrial growth.

World War II -- and the Nation=s need for hydroelectric power soared. At the outbreak of the war, the Axis Nations had three times more available power than the United States. The demand for power was identified in this 1942 statement on AThe War Program of the Department of the Interior@:

> *AThe war budget of $56 billion will require 154 billion kWh of electric energy annually for the manufacture of airplanes, tanks, guns, warships, and fighting material, and to equip and serve the men of the Army, Navy, and Marine Corps.@*

Each dollar spent for wartime industry required about 2-3/4 kWh of electric power. The demand exceeded the total production capacity of all existing electric utilities in the United States. In 1942, 8.5 billion kWh of electric power was required to produce enough aluminum to meet the President=s goal of 60,000 new planes.

Hydropower provided one of the best ways for rapidly expanding the country's energy output. Addition of more powerplant units at dams throughout the West made it possible to expand energy production, and construction pushed ahead to speed up the availability of power. In 1941, Reclamation produced more than five billion kWh, resulting in a 25 percent increase in aluminum production. By 1944, Reclamation quadrupled its hydroelectric power output.

From 1940 through 1945, Reclamation powerplants produced 47 billion kWh of electricity, enough to make:

69,000 airplanes
79,000 machine guns
5,000 ships
5,000 tanks
7,000,000 aircraft bombs, and
31,000,000 shells

During the war, Reclamation was the major producer of power in areas where needed resources were located -- the West. The supply of low-cost electricity attracted large defense industries to the area. Shipyards, steel mills, chemical companies, oil refineries, and automotive and aircraft factories . . . all needed vast amounts of electrical power. Atomic energy installations were located at Hanford, Washington, to make use of hydropower from Grand Coulee.

While power output of Reclamation projects energized the war industry, it was also used to process food, light military posts, and meet needs of the civilian population in many areas.

With the end of the war, powerplants were put to use in rapidly developing peacetime industries. Hydropower has been vital for the West's industries which use mineral resources or farm products as raw materials. Many industries have depended wholly on Federal hydropower. In fact, periodic low flows on the Columbia River have disrupted manufacturing in that region.

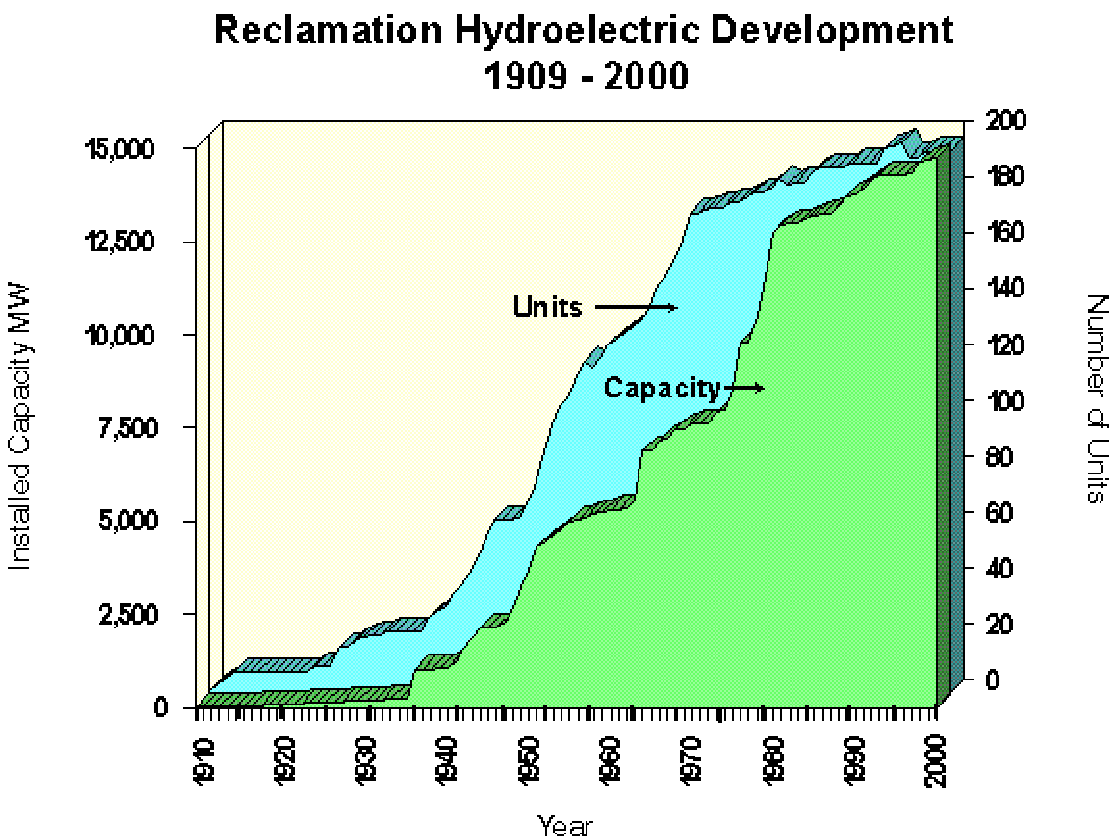
Farming was tremendously important to America during the war and continues to be today. Hydropower directly benefits rural areas in three ways:

-- It produces revenue which contributes toward repayment of irrigation facilities, easing the water users' financial burden.

-- It makes irrigation of lands at higher elevations possible through pumping facilities.

-- It makes power available for use on the farm for domestic purposes.

Reclamation delivers 10 trillion gallons of water to more than 31 million people each year. This includes providing one out of five Western farmers (140,000) with irrigation water for 10 million farmland acres that produce 60% of the nation's vegetables and 25% of its fruits and nuts.



Some of the major hydroelectric powerplants built by Reclamation are located at:

-- Grand Coulee Dam on the Columbia River in Washington (the largest single electrical generating complex in the United States.)
-- Hoover Dam on the Colorado River in Arizona-Nevada.
-- Glen Canyon Dam on the Colorado River in Arizona.
-- Shasta Dam on the Sacramento River in California.
-- Yellowtail Dam on the Bighorn River in Montana.

Grand Coulee has a capacity of more than 6.8 million kW of power. Hydropower generated at Grand Coulee furnishes a large share of the power requirements in the Pacific Northwest.

Reclamation is one of the largest operators of Federal power-generating stations. The agency uses some of the power it produces to run its facilities, such as pumping plants. Excess

Reclamation hydropower is marketed by either the Bonneville Power Administration or the Western Area Power Administration and is sold first to preferred customers, such as rural electric power co-cooperatives, public utility districts, municipalities, and state and Federal agencies. Any remaining power may be sold to private electric utilities. Reclamation generates enough hydropower to meet the needs of millions of people and power revenues exceed $900 million a year. Power revenues are returned to the Federal Treasury to repay the cost of constructing, operating, and maintaining projects.

CONCLUSION

Reclamation is helping to meet the needs of our country, and one of the most pressing needs is the growing demand for electric power. Reclamation powerplants annually generate more than 42 billion kWh of hydroelectric energy, which is enough to meet the annual residential needs of 14 million people or the energy equivalent of more than 80 million barrels of crude oil.

The deregulation of wholesale electricity sales and the imposition of requirements for open transmission access are resulting in dramatic changes in the business of electric power production in the United States. This restructuring increases the importance of clean, reliable energy sources such as hydropower.

Hydropower is important from an operational standpoint as it needs no "ramp-up" time, as many combustion technologies do. Hydropower can increase or decrease the amount of power it is supplying to the system almost instantly to meet shifting demand. With this important load-following capability, peaking capacity and voltage stability attributes, hydropower plays a significant part in ensuring reliable electricity service and in meeting customer needs in a market driven industry. In addition, hydroelectric pumped storage facilities are the only significant way currently available to store electricity.

Hydropower=s ability to provide peaking power, load following and frequency control helps protect against system failures that could lead to the damage of equipment and even brown or blackouts. Hydropower, besides being emissions-free and renewable has the above operating benefits that provide enhanced value to the electric system in the form of efficiency, security, and most important, reliability. The electric benefits provided by hydroelectric resources are of vital importance to the success of our National experiment to deregulate the electric industry.

Water is one of our most valuable resources, and hydropower makes use of this renewable treasure. As a National leader in managing hydropower, Reclamation is helping the Nation meet its present and future energy needs in a manner that protects the environment by improving hydropower projects and operating them more effectively.

GLOSSARY

Alternating Current	An electric current changing regularly from one direction to the opposite.
Ampere	The common unit of measurement of electrical current.
Baseload	The minimum constant amount of load connected to the power system over a given time period, usually on a monthly, seasonal, or yearly basis.
Baseload Plant	A plant, usually housing high-efficiency steam-electric units, which is normally operated to take all or part of the minimum load of a system, and which consequently produces electricity at an essentially constant rate and runs continuously. These units are operated to maximize system mechanical and thermal efficiency and minimize system operating costs.
Bus (buswork)	A conductor, or group of conductors, that serve as a common connection for two or more electrical circuits. In powerplants, buswork comprises the three rigid single-phase connectors that interconnect the generator and the step-up transformer(s).
Capability	The maximum load that a generating unit, generating station, or other electrical apparatus can carry under specified conditions for a given period of time without exceeding approved limits of temperature and stress.
Capacity	The amount of electric power delivered or required for which a generator, turbine, transformer, transmission circuit, station, or system is rated by the manufacturer.
Circuit	A conductor or a system of conductors through which electric current flows.
Current (Electric)	A flow of electrons in an electrical conductor. The strength or rate of movement of the electricity is measured in amperes.
Dam	A massive wall or structure built across a valley or river for storing water.

Demand	The rate at which electric energy is delivered to or by a system, part of a system, or a piece of equipment. It is expressed in kilowatts, kilovolt amperes, or other suitable units at a given instant or averaged over any designated period of time. The primary source of "demand" is the power-consuming equipment of the customers.
Direct Current	Electric current going in one direction only.
Distribution System	The portion of an electric system that is dedicated to delivering electric energy to an end user. The distribution system "steps down" power from high-voltage transmission lines to a level that can be used in homes and businesses.
Energy	The capacity for doing work as measured by the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy). Energy has several forms, some of which are easily convertible and can be changed to another form useful for work. Most of the world's convertible energy comes from fossil fuels that are burned to produce heat that is then used as a transfer medium to mechanical or other means in order to accomplish tasks. Electrical energy is usually measured in kilowatt hours and represents power (kilowatts) operating for some time period (hours), while heat energy is usually measured in British thermal units.
Generation (Electricity)	The process of producing electric energy by transforming other forms of energy; also, the amount of electric energy produced, expressed in watthours (Wh).
Generator	A machine that converts mechanical energy into electrical energy.
Head	The difference in elevation between the headwater surface above and the tailwater surface below a hydroelectric powerplant under specified conditions.
Horsepower	A unit of rate of doing work equal to 33,000 foot pounds per minute or 745.8 watts (Brit.), 746 watts (USA), or 736 watts (Europe).
Hydroelectric Power	Electric current produced from water power.
Hydroelectric Powerplant	A building in which turbines are operated, to drive generators, by the energy of natural or artificial waterfalls.

Kilowatt (kW)	Unit of electric power equal to 1,000 watts or about 1.34 horsepower. For example, it's the amount of electric energy required to light ten 100-watt light bulbs.
Kilowatt-Hour (kWh)	The unit of electrical energy commonly used in marketing electric power; the energy produced by 1 kilowatt acting for one hour. Ten 100-watt light bulbs burning for one hour would consume one kilowatt hour of electricity.
Kinetic Energy	Energy which a moving body has because of its motion, dependent on its mass and the rate at which it is moving.
Load (Electric)	The amount of electric power delivered or required at any specific point or points on a system. The requirement originates at the energy-consuming equipment of the consumers.
Megawatt	A unit of power equal to one million watts. For example, it's the amount of electric energy required to light 10,000 100-watt bulbs.
Ohm	The unit of measurement of electrical resistance. The resistance of a circuit in which a potential difference of one volt produces a current of one ampere.
Peakload	The greatest amount of power given out or taken in by a machine or power distribution system in a given time.
Power	Mechanical or electrical force or energy. The rate at which work is done by an electric current or mechanical force, generally measured in watts or horsepower.
Pumped-Storage Hydroelectric Plant	A plant that usually generates electric energy during peak-load periods by using water previously pumped into an elevated storage reservoir during off-peak periods when excess generating capacity is available to do so. When additional generating capacity is needed, the water can be released from the reservoir through a conduit to turbine generators located in a power plant at a lower level.
Rated Capacity	That capacity which a hydro generator can deliver without exceeding mechanical safety factors or a nominal temperature rise. In general this is also the nameplate rating except where turbine power under maximum head is insufficient to deliver the nameplate rating of the generator.

Reservoir	An artificial lake into which water flows and is stored for future use.
Turbine	A machine for generating rotary mechanical power from the energy of a stream of fluid (such as water, steam, or hot gas). Turbines convert the kinetic energy of fluids to mechanical energy through the principles of impulse and reaction, or a mixture of the two.
Volt (V)	The unit of electromotive force or potential difference that will cause a current of one ampere to flow through a conductor with a resistance of one ohm.
Watt (W)	The unit used to measure production/usage rate of all types of energy; the unit for power. The rate of energy transfer equivalent to one ampere flowing under a pressure of one volt at unity power factor.
Watthour (Wh)	The unit of energy equal to the work done by one watt in one hour.